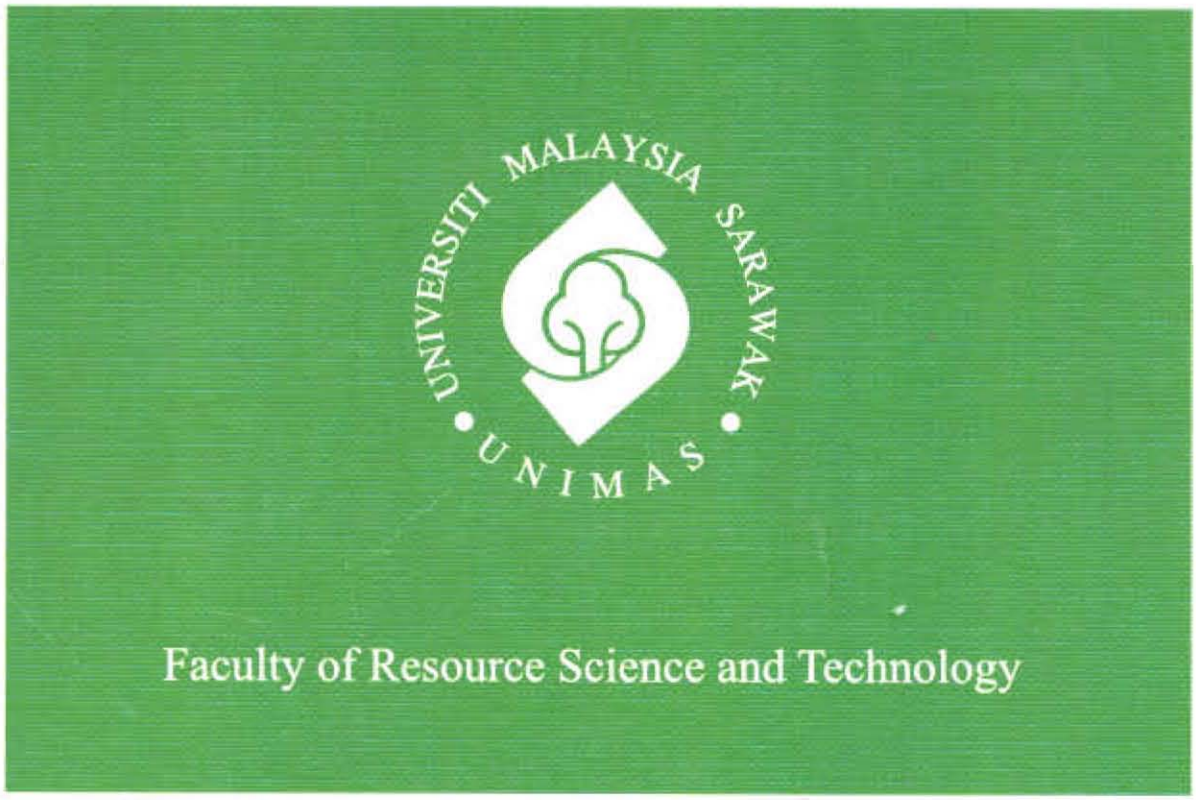

Assessment of The Soil Fertility Status of Lands Under Upland Farming Practices at Sabal, Sarawak, Malaysia

Ho Soo Ying

Master of Science
(Soil Science)
2015

UNIVERSITI MALAYSIA SARAWAK

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PhD	☐

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This declaration is made on the 15th day of DECEMBER 2015.

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ASSESSMENT OF THE SOIL FERTILITY STATUS OF LANDS UNDER UPLAND FARMING PRACTICES AT SABAL, SARAWAK, MALAYSIA

HO SOO YING

A thesis submitted
In fulfillment of the requirements for the degree of
Master in Science (Soil Science)

Faculty of Resource Science and Technology
UNIVERSITI MALAYSIA SARAWAK
2015

DECLARATION

I hereby declare that this thesis entitled **Assessment on the Soil Fertility Status of Lands under Upland Farming Practices at Sabal, Sarawak, Malaysia** is my own original work and has not been submitted in any form for another degree or diploma at any university or other institute of tertiary education. Information derived from the published and unpublished work of others has been acknowledged in the text and a list of reference is given.

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Assessment on the Soil Fertility Status of Lands under Upland Farming Practices at Sabal, Sarawak, Malaysia

Ho Soo Ying

ABSTRACT

Rapidly changing land uses at the upland areas due to the need of subsistence and monetary income have resulted in the intensification of upland agriculture. Incorporation of various agrochemicals on a permanent cultivation land could be detrimental to the tropical environment especially on the naturally fragile upland soils. Various efforts are progressing towards sustaining the soil resources at the upland areas. However, very limited information are available on the current soil fertility and nutrient status under intensified form of agricultural practices via cash crops cultivation at the upland areas of Sarawak. In this study, assessment on the soil nutrient status under various perennial cash crops farming by smallholder farmers at upland area of Sabal was conducted. The soil fertility in these farmlands was determined using soil indices, notably Soil Evaluation Factor (SEF). In addition, the study also clarified the influence of current land management practices on soil nutrient stocks under cash crops cultivation. This study was conducted at Sabal, Sarawak where majority of the communities are smallholder farmers and presently conduct various forms of cash crop farming. Soil samples were collected at the depth of 0-10 cm and 30-40 cm from various land uses namely: secondary forest, rubber, *Hevea brasiliensis*; oil palm, *Elaeis guineensis* and pepper, *Piper nigrum* farmlands for soil physicochemical analysis. Additional soil samples were also collected from the fertilizing points at 0-10 cm depth of oil palm stands and pepper vines. Soil profile descriptions were conducted at the representative study sites to collect the baseline data of the soils at the study area. Interview with the farmland owners were also conducted to obtain information on family background, land use history and cultural practices. The results showed that there were different types of land management practices for the cash crop farming in the study area. In general, only small amount of fertilizers were applied in young rubber farmlands as compared to oil palm and pepper farmlands. On average, approximately 0.2 t ha^{-1} to 6.8 t ha^{-1} of compound N-P-K fertilizers were applied annually at oil palm and pepper farmlands. With regard to the different land uses, the soils at the study area were acidic in nature, characterized by sandy texture with low exchangeable bases (K, Mg and Ca). The clay contents and soil Total C were low thus, corresponds to low soil CEC level at the study area. Various land uses were further divided into young secondary forest (Y-SF), old secondary forest (O-SF), before tap rubber farmland (BT-R), after tap rubber farmland (AT-R), before harvest oil palm farmland (BH-OP), after harvest oil palm farmland (AH-OP), before harvest pepper farmland (BH-P) and after harvest pepper farmland (AH-P). In terms of soil physicochemical properties, among different land uses, rubber farmlands resembled to those in secondary forest. Meanwhile, accumulation of nutrient contents, notably soil available P as the effect of fertilizers application was observed in oil palm and pepper farmlands. In addition, soils at both oil palm and pepper farmlands showed high soil bulk density and soil hardness, indicating considerable soil compaction due to regular farm work and maintenance. At the surface soils (0-10 cm), the BH-P farmlands showed the greatest SEF value which was 9.58, followed by Y-SF (9.09), BT-R farmlands (9.04), AH-OP farmlands (8.98), O-SF (6.84), BH-OP farmlands (6.79) and least for AT-R farmlands (6.62). In terms of

soil nutrient stocks under various crops cultivation, the soil nutrient stock under AT-R farmlands were low and similar to those in O-SF. Conversely, soil nutrient stocks in AH-OP farmlands and AH-P farmlands were higher as compared to O-SF, as fertilizers were added into the soils regularly for crops production. As farmers were able to produce satisfactory latex yield, current rubber farming with minimal input of fertilizers and soil disturbances can be regarded as sustainable at the uplands of Sabal. However, the intensified oil palm and pepper cultivation should be reconsidered as it involves significant use of agrochemicals, particularly oil palm cultivation which occupied a larger farmlands area. Knowledge on agrochemicals, especially on fertilizers application along with crop nutrient requirements should be enhanced among the farmers to ensure the effective use of agrochemicals. Furthermore, appropriate and strategic land use planning as well as techniques of good agricultural practice (GAP) should be incorporated and adapted by the local farmers in conserving soil fertility towards sustainable upland agriculture in the future.

***Keywords*: Upland agriculture, Sarawak, cash crops, soil nutrient status, Soil Evaluation Factor (SEF)**

Penilaian Kesuburan Tanah berdasarkan Amalan Pertanian Semasa di Kawasan Tanah Tinggi Sabal, Sarawak.

Ho Soo Ying

ABSTRAK

Perkembangan dalam perubahan penggunaan tanah semasa di tanah tinggi untuk memenuhi keperluan pendapatan telah mendorong kegiatan pertanian tanah tinggi secara intensif. Amalan penggunaan pelbagai jenis agrokimia yang kerap di kawasan pertanian tetap akan memudaratkan alam sekitar, terutamanya di tanah tinggi yang mempunyai sumber tanah yang rapuh. Pelbagai usaha telah dilakukan untuk mengamalkan aktiviti pertanian yang mapan di kawasan tanah tinggi. Walaubagaimanapun, informasi semasa tentang kesuburan tanah di bawah penanaman tanaman tunai secara intensif di kawasan tanah tinggi masih terhad, terutamanya di Sarawak, Malaysia. Justeru, kajian ini bertujuan untuk menilai status nutrien tanah di bawah pelbagai tanaman tunai secara intensif oleh pekebun kecil tempatan di kawasan tanah tinggi, Sarawak. Faktor Penilaian Tanah (SEF) digunakan untuk menentukan kesuburan tanah di kawasan pertanian tersebut. Di samping itu, kajian ini juga menjelaskan pengaruh amalan pengurusan tanah semasa kepada stok nuutrien tanah di kawasan penanaman tanaman tunai. Kawasan kajian terletak di Sabal, Sarawak di mana majoriti masyarakat adalah pekebun kecil yang menanam tanaman tunai. Sampel tanah pada kedalaman 0-10 cm dan 30-40 cm telah dikumpulkan di kawasan hutan sekunder, kebun getah Hevea brasiliensis; kebun kelapa sawit, Elaeis guineensis dan kebun lada hitam; Piper nigrum untuk analisis sifat fizikal-kimia tanah. Sampel tanah tambahan juga dikumpulkan di kedalaman 0-10 cm di tempat pembajaan di bawah kanopi kelapa sawit dan batang lada. Profile tanah juga dilakukan di beberapa kawasan pertanian yang terpilih untuk mengumpul data asas tanah di kawasan kajian. Kajian soal selidik dilaksanakan untuk pengumpulan maklumat seperti latar belakang keluarga, sejarah penggunaan tanah, serta cara penanaman tanaman tunai. Kajian menunjukkan pelbagai teknik pengurusan tanah diamalkan oleh pekebun kecil untuk tanaman tunai yang berbeza. Hanya sedikit baja yang ditaburkan di kawasan penanaman getah muda berbanding dengan kelapa sawit dan lada hitam. Baja kompaun N-P-K yang mempunyai purata 0.2 t ha^{-1} hingga 6.8 t ha^{-1} ditaburkan di kawasan pertanian kelapa sawit dan lada hitam. Analisis menunjukkan tanah di kawasan kajian adalah berasid, mempunyai tekstur tanah yang berpasir dan mempunyai kandungan K, Ca dan Mg yang rendah. Kandungan tanah liat dan jumlah C yang rendah telah menyebabkan tahap CEC yang rendah di kawasan kajian. Kawasan kajian telah diahagikan kepada hutan sekunder muda (Y-SF), hutan sekunder tua (O-SF), kebun getah sebelum tuai (BT-R), kebun getah selepas tuai (AT-R), kebun kelapa sawit sebelum tuai (BH-OP), kebun kelapa sawit selepas tuai (AH-OP), kebun lada hitam sebelum tuai (BH-P), dan kebun lada hitam selepas tuai (AH-P). Dari segi sifat fisikal-kimia tanah, kawasan tanaman getah menunjukkan persamaan dengan hutan sekunder. Pengumpulan nutrien di dalam tanah akibat daripada pembajaan

lebihan, terutamanya P ditemui di kawasan penanaman sawit dan kawasan penanaman lada hitam. Di samping itu, kawasan penanaman kelapa sawit dan lada, ketumpatan dan kekerasan tanah yang tinggi menunjukkan kekerapan kerja-kerja penyelenggaraan di kebun tersebut telah memberi kesan kepada kepadatan tanah. Pada permukaan tanah (0-10 cm), tanah di kebun (BH-P) menunjukkan nilai SEF yang paling tinggi, diikuti oleh Y-SF (9.09), kebun BT-R (9.04), kebun AH-OP (8.98), hutan O-SF (6.84), kebun BH-OP (6.79), kebun AT-R (6.62) dan kebun (AT-R). Stok nutrien tanah di kawasan AT-R adalah rendah dan mempunyai persamaan dengan O-SF. Sebaliknya, stok nutrien tanah di kebun AH-OP dan AH-P adalah lebih tinggi berbanding dengan O-SF atas kesan pembajaan yang kerap untuk pengeluaran hasil tanaman. Memandangkan pekebun kecil tempatan mampu mengeluarkan hasil susu getah yang memuaskan, penanaman getah di kawasan tanah tinggi yang mempunyai input baja serta gangguan tanah yang minima boleh dianggap sebagai pertanian mapan di kawasan tanah tinggi Sabal. Sebaliknya, penanaman lada dan kelapa sawit perlu dipertimabangkan kerana tanaman tunai tersebut melibatkan penggunaan bahan agrokimia. Ilmu pengetahuan mengenai penggunaan bahan agrokimia, khususnya baja harus dipertingkatkan dalam kalangan petani untuk memastikan keberkesanan dalam penggunaan bahan agrokimia pertanian. Selain itu, perancangan penggunaan tanah yang strategik serta teknik-teknik amalan pertanian baik (GAP) perlu diperkenalkan dan diadaptasi oleh pekebun kecil tempatan untuk pemuliharaan kesuburan tanah dalam pencapaian pertanian mapan di kawasan tanah tinggi pada masa yang akan datang.

Kata kunci: Pertanian tanah tinggi, Sarawak, tanaman tunai, status nutrien tanah, Faktor Penilaian Tanah (SEF)

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LIST OF ABBREVIATIONS

%	Percentage
<	Less than
>	More than
°	Degree
°C	Degree Celcius
μScm^{-1}	micro Siemen per centimetre
Al	Aluminium
B	Boron
C	Carbon
Ca	Calcium
CaO	Calcium oxide
CEC	Cation Exchange Capacity
cm	centimetre
cm^3	centimetre cubed
$cmol_c kg^{-1}$	centimole charge per kg
EC	Electrical Conductivity
ECEC	Effective CEC
FP	Fertilizing point
g	gram
$g\ kg^{-1}$	gram per kilogram
gmL^{-1}	gram per millimetre
H	Hydrogen
ha	hectare

ha^{-1}	per hectare
HCl	Hydrogen Chloride
K	Potassium
KCl	Potassium Chloride
kg	kilogram
kg yr^{-1} ha^{-1}	kilogram per year per hectare
m	metre
M	Molarity
Mg	Magnesium
mg P kg^{-1}	milligram P per kilogram
MgO	Magnesium Oxide
MgO	Magnesium oxide
mm	millimetre
mt	metric ton
N	Nitrogen
N FP	Non-fertilizing point
Na	Sodium
NaCl	Sodium chloride
NADPH	Reduced Nicotinamide Adenine Dinucleotide Phosphate
NaOH	Sodium Hydroxide
NGOs	Non-Governmental Organizations
NH_4F	Ammonium Fluoride
nm	nanometre
P	Phosphorus

POME	Palm oil mill effluent
ppm	parts per million
rpm	revolutions per minute
RRIM	Rubber Research Institute of Malaysia
SEF	Soil Evaluation Factor
SOM	Soil Organic Matter
t	tonne
t ha^{-1}	tonne per hectare
t yr^{-1} ha^{-1}	tonne per year per hectare
TE	Trace Elements
trees ha^{-1}	trees per hectare
USDA	United States Department of Agriculture

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1.0 INTRODUCTION

1.1 Study Background

Upland farming is referred as agricultural land or activities that is established and prevailed on slope or steepland of the mountainous region that consists of unsubmerged and well-aerated soil (Gomez and Gomez, 1983). Across the Southeast Asia region, the rural households, especially those reside at the interior and remote uplands are still largely dependent on these land areas to sustain their livelihood in providing food, income, fuel, medicine and land for farming (Hong, 1987; Ramakrishnan, 1992; Kleinman *et al*., 1995; Watanabe *et al.*, 2004).

Aminuddin *et al.* (1990) reported that Malaysia has a total land area of 33.03 million ha, with the total upland area estimated about 22.50 million ha. In Sarawak, the total land area is recorded as 12.40 million ha (Teng, 2003). However, 7.17 million ha (67%) are steeplands with hilly and steep terrain with limitations of erosion hazard that require proper land management practices when used for agricultural production (Teng, 2003). On the other hand, in terms of agricultural capability, only 1.78 million ha (14%) of the total 12.40 million ha of land area in Sarawak are suitable for agriculture. The remaining of 10.62 million ha (86%) are classified as marginally suitable to conditionally suitable for agriculture where most of these land were located at the upland area. The occurrence of steeplands throughout the state of Sarawak can be found within different topography and slope steepness. At those areas, the common soil type found are Red-Yellow Podzolic Soils and Skeletal Soils under Sarawak Soils Classification System which corresponds to Ultisols and Oxisols in the USDA soil classification system (Teng, 2004). Moreover, soils covering such area are highly weathered

and infertile with acidic properties, low cation exchange capacity and base saturation under intense weathering conditions in the tropical environment (Aminuddin *et al.*, 1990).

At present, two common form of agricultural practices existed at the upland areas of Sarawak, predominantly subsistence farming via shifting cultivation and cash crop farming via permanent cultivation. For decades, shifting cultivation is known as an age-old, primitive farming system that has been widely practice in the uplands of Sarawak till today (Padoch *et al.*, 2007). Initially, the desired land is cleared and burnt as preparation for the cultivation of upland rice. After each cycle of cropping period, the land will be abandoned for vegetation regeneration and soil recovery before they move to the similar land for next cultivation. Thus, shifting cultivation is considered as an ideal solution for soil fertility in the humid tropics (Watters, 1971; Kleinman *et al.*, 1995). Likewise, such agriculture is considered well-adapted to the interior uplands that often classified as marginally and conditionally suitable for agriculture purposes in the Sarawak (Teng, 1991). Successful rotation of soil recovery normally requires considerable fallow period for the purpose to restore the soil fertility lost during cropping period (Sanchez, 1995). However, such agricultural system is extremely fragile and destructive under land and population pressure (Hatch and Lim, 1978; Hong, 1987).

On the other hand, farmers also cultivate rubber (*Hevea brasiliensis*) and pepper (*Piper nigrum*) as perennial cash crops in addition to upland rice cultivation as their source of staple food (Tanaka *et al.*, 2009). Rubber and pepper were introduced to Sarawak in the 1870s and 1900s respectively (Cramb; 2007; Tanaka *et al.*, 2014). According to Cramb (2007), rubber can be easily incorporated into the shifting cultivation system by planting the seedlings simultaneously during or after the rice cropping period while pepper cultivation became widespread due to the availability of agrochemicals provided by government agencies and less

labour intensive as compared to the traditional agricultural practice. Nowadays, rapid changes in socio-economic condition of rural farmers in parallel to the industrialism development in Sarawak has encouraged the farmers to realize the importance of cash crop farming in fulfilling the need of monetary income. As a consequence, the shifting cultivation practices which previously act as the central form of agricultural system in the uplands had undergone transformation into a more diversified and complex upland farming systems (Tanaka *et al.*, 2009; Wasli *et al.*, 2009), where the subsistence shifting cultivation as well as permanent cash crop farming system coexist and prevail at the uplands of Sarawak. Furthermore, oil palm has been cultivated commercially through government agencies and private plantation companies in the 1970s and 1980s (Ngidang, 2002; Cramb; 2007) and recently gaining popularity among the financially stable smallholder farmers. Under such condition, commercialism in cash crops increased dramatically when government agencies such as Malaysian Pepper Board (MPB), Malaysian Palm Oil Board (MPOB) and Department of Agriculture (DOA) offer various kinds of smallholder subsidy schemes to the farmers (Ichikawa, 2007).

At present, the total land area under perennial cash crops in Sarawak were estimated to be 159,000 ha for rubber, 15,000 ha for pepper and 1,022,000 ha for oil palm in 2011, which accounted for 11.0%, 1.0% and 70.5% of the total agricultural land, respectively (Department of Agriculture Sarawak, 2011). In addition, the area used for oil palm cultivation has expanded drastically from 508,307 ha in year 2004 to 1,022,000 ha in 2011. Meanwhile, rubber and pepper cultivation had increased slightly from 156,731 ha to 159,000 ha and 12,930 ha to 15,000 ha, respectively. Based on the statistics reported by Department of Agriculture Sarawak (2011), it is noticeable that agricultural land for oil palm cultivation has

expanded rapidly either plantation based or smallholder based due to the high global demand for crude palm oil (CPO).

Meanwhile, rapid growth of human population, illegal logging activities and timber plantation, along with dam construction as well as the governments' policy in the conversion of native customary land into a titled commercial agricultural land like oil palm plantation, accelerates deforestation and land clearing which had extended to most of the upland areas in Sarawak (Ngidang, 2002). Due to competition in searching new land for faming, such scenario had indirectly promoted the transitional changes in the traditionally practiced subsistence farming into a more sedentary and intensive farming practices, notably reduction of fallow length and the incorporation of agrochemicals during cropping period (Kendawang *et al.*, 2004; Ichikawa, 2007; Wasli *et al.*, 2009; Schreinemachers *et al.*, 2013). In addition, the limitation of arable lands has forced farmers to utilize the unsuitable, infertile land for cash crop farming (Ishizuka *et al.*, 2000). Likewise, cash crops are intensively cultivated and established on a permanent agricultural land, involving significant application of agrochemicals throughout a long cropping period (Kendawang *et al.*, 2004; Dalle *et al.*, 2006; Boonyanuphap *et al.*, 2007; Tanaka *et al.*, 2009).

As reported by Hardaker *et al.* (1993), the nature of upland areas is environmentally fragile and sensitive to over-exploitation from human-induced degradation. The vulnerability of the marginal upland soil resources is therefore unpredictable under such permanent agricultural practice of shortening of fallow length as well as usage of agrochemicals. Some researchers reported the degradation of upland soil resources due to improper implementation of land use management and illiteracy of agrochemicals usage such as nutrient imbalance, over-application of fertilizers, pesticides pollution, surface runoff and erosion (Zhang *et al.*,